MONITORING DISTURBANCES AND CHANGE ON THE SAN JUAN NATIONAL FOREST

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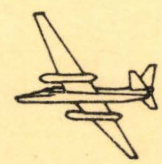

NATIONWIDE FORESTRY APPLICATIONS PROGRAM

FINAL REPORT

MONITORING DISTURBANCES AND CHANGE ON THE SAN JUAN NATIONAL FOREST

by

DAMIEN L. LEPOUTRE

A report submitted in fulfillment of a 9-month on-the-job-training assignment in remote sensing applied to Forest Resource Analysis and Inventory sponsored jointly by the Governments of France and the United States.

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16. Abstract (Limit: 200 words)

This document reports the results of a change detection feasibility study performed on the San Juan National Forest in Colorado involving personnel and facilities of the Forest Service's Nationwide Forestry Applications Program and the Rocky Mountain Region. Investigation techniques involved the use of high altitude color infrared photography achieved with the ACTRON HR732 large format camera flown on a NASA, U-2C aircraft and a Digital Image Analysis and Display System. The results of photo-interpretation and computer-assisted techniques for monitoring disturbances and change on the forest are presented.

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FOREWORD

During the period October 1980 through June 1981, Mr. Damien L. Lepoutre was assigned to the U.S. Department of Agriculture, Forest Service, Nationwide Forestry Applications Program in Houston, Texas, on a training exchange program arranged with the Ministere de l' Agriculture in France. The training Mr. Lepoutre received in remote sensing applied to problems in forest management, planning and inventory in the United States was creditable for academic requirements at his college in France, the Ecole Nationale due Genie Rural, des Eeasux et des Forets.

Mr. Lepoutre's work provided substantial new information on applying heretofore theoretical methods of change detection and monitoring in a field-oriented applications feasibility test. The results of his studies are now being applied in an operational test of monitoring changes under the San Juan National Forest land management plan.

FREDERICK P. WEBER, Program Manager

NATIONWIDE FORESTRY APPLICATIONS PROGRAM

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The author would first like to thank the Nationwide Forestry Applications (NFA) Program personnel for their friendship and help to my family during our stay in Houston.

The author would especially like to thank Dr. F. P. Weber for allowing me to work nine (9) months on his program and providing me an invaluable experience in remote sensing; Pat Malpass for her continuous assistance and support and for typing my reports; and Jim Bell whose field knowledge was very much appreciated.

Dr. John Colwell and Fred Thomson of the Environmental Research Institute of Michigan (ERIM) deserve special thanks for their willingness to share their experience with me and their contribution to my training.

The author would like also to thank the San Juan National Forest (Region 2) personnel and especially Hank Bond for their welcome and help during my field trip to Durango, Colorado.

Special thanks are extended to NASA/Johnson Space Center personnel, particularly to Rig Joosten; and to Vic Mazade and his team at Lockheed Engineering and Management Services Company, Inc. for their interest and support for my study. Dick Liston, Forest Service, Washington Office, is acknowledged for invaluable assistance provided in the DIADS familiarization phase of the work.

ACRONYMS AND ABBREVIATIONS

AgRISTARS	Agriculture and Resources Inventory Surveys Thourgh Aerospace Remote Sensing
CCT	computer compatible tape
CIR	color infrared film
CVA/BLOB	change vector analysis and "BLOB" (not an acronym) algorithm
DEC	Digital Equipment Corporation
DIADS	Digital Image Analysis and Display System
ERDC	Earth Resources Data Center (at ERIM)
ERIM	Environmental Research Institute of Michigan
EROS	Earth Resources Observations System (U.S. Department of Interior)
FS	Forest Service
GSFC	Goddard Space Flight Center (NASA)
HAP	high altitude photography
IFOV	instantaneous field of view
LEMSCO	Lockheed Engineering and Management Services Company, Inc.
LFC	large format camera
NASA	National Aeronautics and Space Administration
NFAP	Nationwide Forestry Applications Program
RAS	remote analysis station
R2MAP	Region 2 mapping system
RRI	Renewable Resources Inventory
SJNF	San Juan National Forest
USDA	United States Department of Agriculture
USGS	U.S. Geological Survey

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1. INTRODUCTION

This report documents the results of a change detection feasibility study in the Mancos District of the San Juan National Forest, Colorado. Personnel and facilities of both the Forest Service's Nationwide Forestry Applications Program and Rocky Mountain Region (R-2) were involved in this investigation. Essentially, this report describes the techniques used to detect and monitor change in the Forest using the ACTRON HR-732 large format camera, Kodak SO-131 high definition color infrared film obtained during two missions in 1978 and 1980 from a NASA U-2C aircraft and the Digital Image Analysis and Display System. The results from photointerpretation and computer-assisted techniques for monitoring disturbances and change on the forest are presented in detail.

1.1 THE NATIONWIDE FORESTRY APPLICATIONS (NFA) PROGRAM

1.1.1 BACKGROUND

In 1976, the Nationwide Forestry Applications (NFA) Program was expanded from a Regional project by cooperative agreement between the U.S. Department of Agriculture, Forest Service and the National Aeronautics and Space Administration (NASA).

The program is designed to sponsor research and development on the application of remote sensing analysis techniques to problems arising from the need to inventory, monitor and manage forests and rangelands, including the assessment of impacts on forest stands from insect and disease damage.

1.1.2 CHARTER

The NFA Program is a major vehicle for implementation of new remote sensing technology into operational use in the Forest Service. In service to all branches of the Forest Service, the NFA Program has a National charter to:

- Identify and investigate new remote sensing technology
- Develop, test and evaluate remote sensing technology for application in the Forest Service
- Perform large scale demonstration pilot tests as a means of validating the utility and cost effectiveness of remote sensing technology
- Assist in the implementation of remote sensing technology in operational units of the Forest Service by providing Regional assistance and training as a part of the technology transfer process.

1.1.3 AgRISTARS

In 1980, the Forest Service became a part of the AgRISTARS program with responsibility in the Renewable Resources Inventory (RRI) Project assigned by the Secretary of Agriculture to the Chief of the Forest Service. The NFA Program was directed to manage the RRI Project within its existing Program management structure. All remote sensing research was consolidated into the RRI Project.

RRI is one of eight projects identified in a joint program for Agriculture and Resources Inventory Surveys through Aerospace Remote Sensing called AgRISTARS.

AgRISTARS is jointly funded by the Departments of Agriculture, Interior, Commerce, State and the National Aeronautics and Space Administration to sponsor remote sensing research to benefit agricultural (including forestry) programs.

1.1.4 PROBLEM AREAS

The NFA Program charter identified seven major problem areas of investigation with the common link being remote sensing. Technical tasks are identified annually in each problem area, and are assigned to a project depending on the nature of the task. The seven problem areas are:

1. Current Remote Sensing Technology Assessment
2. New Remote Sensing Technology Development
3. Inventory Techniques Improvement
4. Detection, Classification and Measurement of Disturbances
5. Classification, Modeling and Measurement of Renewable Resources
6. Determination of Site Suitability and Land Management Planning
7. Storage and Retrieval of Remote Sensing Data from a Geographic Information Data Base

1.1.5 PROGRAM ORGANIZATION

The NFA Program is divided into five projects for dealing with program goals and objectives which are covered by different time-dependent factors. The five projects are:

1. Remote Sensing Development Project
2. Remote Sensing Implementation Project
3. Remote Sensing Support Project

4. Large Scale Demonstration Project

5. Renewable Resources Inventory Project (AgRISTARS)

An organization chart is presented in figure 1-1 as well as a task assignment flow chart in figure 1-2.

1.2 THE SAN JUAN NATIONAL FOREST

The San Juan National Forest is one of 16 National Forests in Region 2 of the National Forest System. It is located in Colorado near the point where Colorado, New Mexico, Arizona and Utah meet (see figure 1-3). It encompasses an area of 850,000 hectares (2.1 million acres) of which 96,000 hectares (237,000 acres) are in state, county, municipal, private or other Federal ownership.

1.2.1 GEOLOGY AND TOPOGRAPHY

Elevations range from 1,980 to 4,267 meters (6,500 to 14,000 feet). The Forest is characterized by a diversity of terrains such as; flat mesas, deep canyons, rolling foothills and steep rugged mountains. The physical features of mountains, valleys, plateaus and mesas are closely related to their underlying geology, particularly resistant igneous formations. The sedimentary formation of the eastern portion of the Forest was modified by volcanic flow rocks and intrusives overlying the granite basement rock. Granites and schists are mainly exposed in the south and southeast portion of the Forest. The west central and western part of the Forest contains sediments and meta-sediments with some igneous intrusives. The sedimentary rocks are chiefly sandstones, limestones and shales. Landslides have

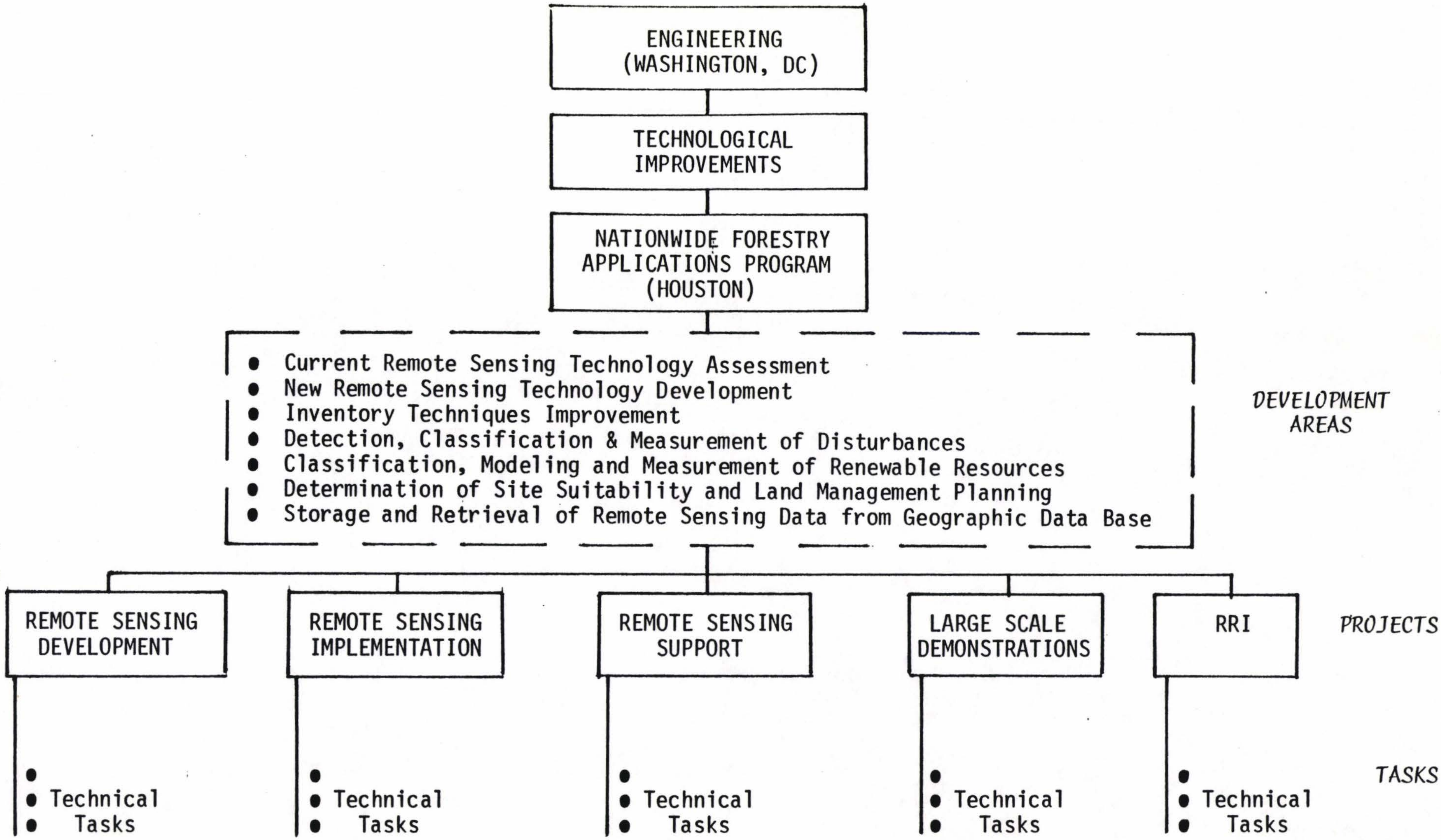

FIGURE 1-1 - NATIONWIDE FORESTRY APPLICATIONS (NFA) PROGRAM - ORGANIZATION

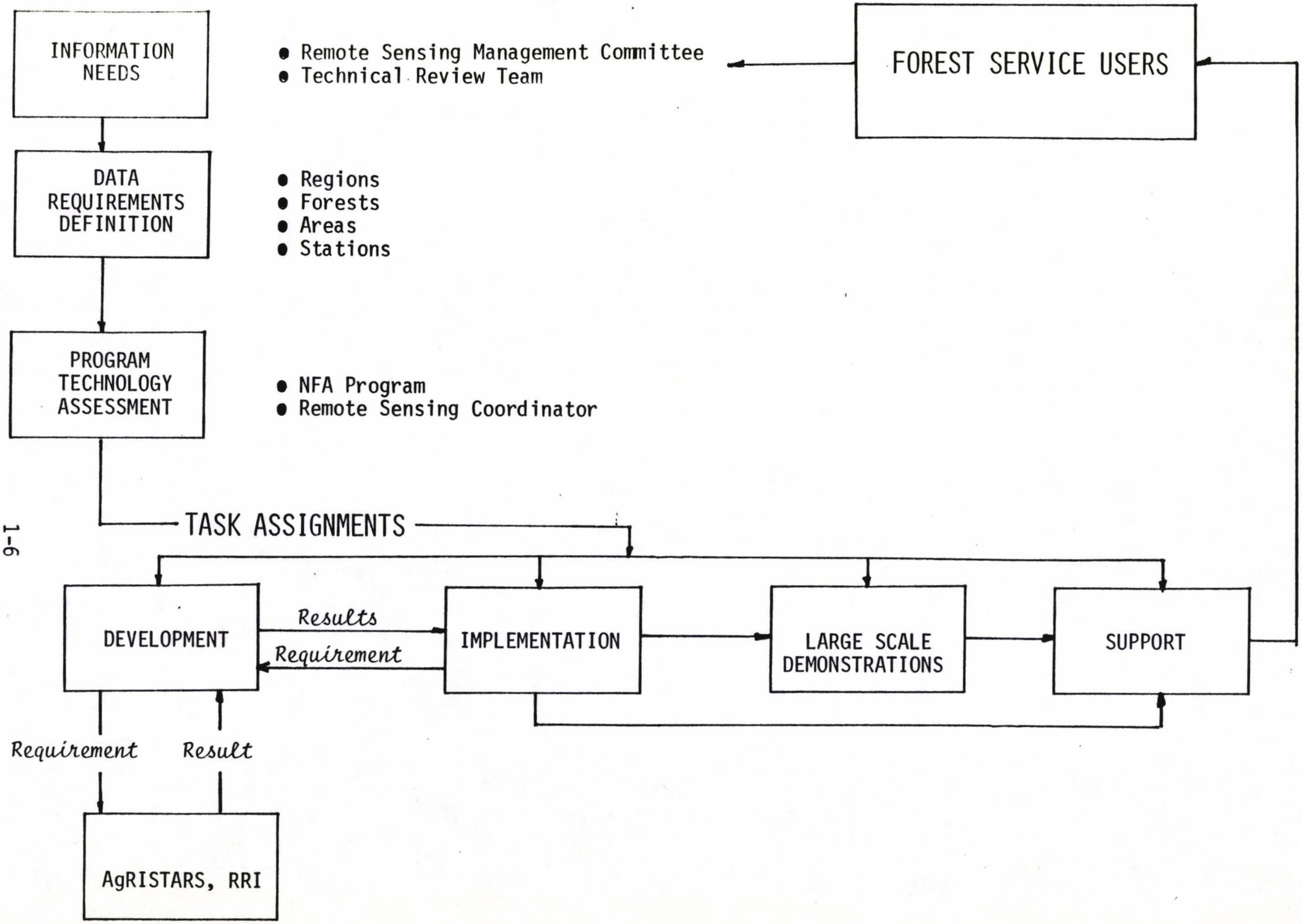

FIGURE 1-2 - NATIONWIDE FORESTRY APPLICATIONS (NFA) PROGRAM - TECHNICAL TASK ASSIGNMENT

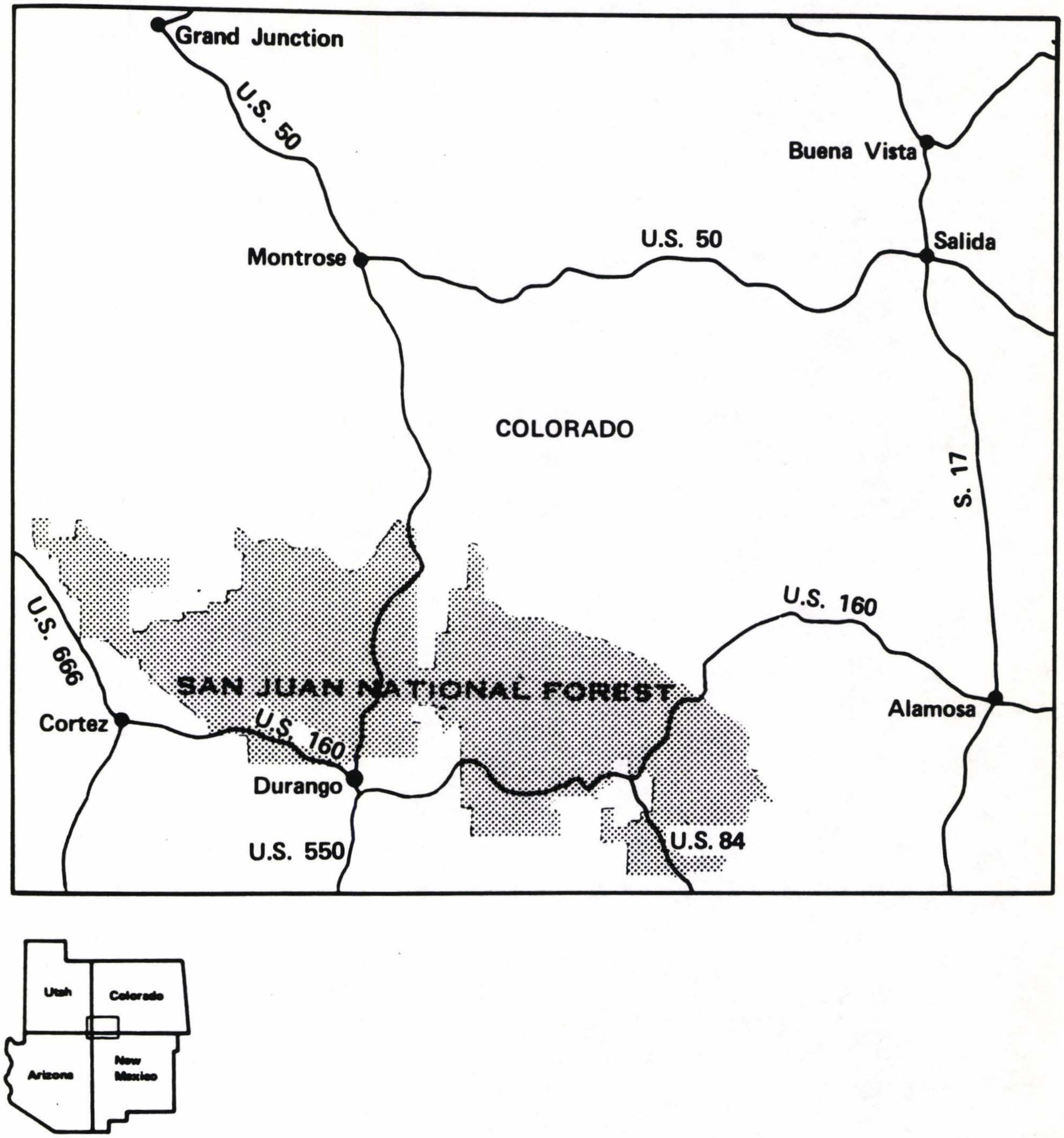

Figure 1-3.- Vicinity map of the San Juan National Forest, Colorado.

shaped areas where hard massive beds overlying soft yielding beds have been exposed on fairly steep slopes.

1.2.2 VEGETATIVE ZONES

The most common vegetative zones in the San Juan National Forest are pinyon-juniper, pine-oakbrush, spruce-fir, and alpine tundra.

- Between 1,980 and 2,400 meters (6,500 and 8,000 feet), pinyon pine, junipers and gambel oaks are the predominant tree species and are usually found on the rough foothills and valleys between mountain ranges. Narrow leaf cottonwood, maple, willow, and alder are found along the streams. On the upper half of this elevation strata, the main vegetation type is ponderosa pine and gambel oak. This tree population attains forest proportions sporadically so that openings for grass, shrubs, and wild flowers are abundant.
- Between 2,400 and 3,000 meters (8,000 and 10,000 feet), Douglas-fir, white fir, and aspen become more dense and water birch and willow are lined on the stream banks.
- The sub-alpine (timberline) zone is found between 3,000 and 3,500 meters (10,000 and 11,500 feet). Soil and moisture are favorable for tree growth, but the snow may remain until summer, and frost is a common occurrence in midsummer thus creating problems of seed production, germination, and survival for the tree species. Some dense forests exist, but the normal pattern is one of small, compact tree groups with patches of grass between. Large mountain meadows and most of the mountain lakes are found at this elevation.

- Over the timberline (over 3,500 meters or 12,500 feet), shallow soils and harsh climate limit the life to lichens, mosses, and other low herbaceous and shrubby plants.

The vegetation zones described above have a high tendancy to integrate from one to another and several species may be found in several zones. A particular tree may be found on two different elevations in two different areas of the forest because of a high variability of local conditions. However, aspect and elevation determine to some extent the location of the cover types (see figure 1-4).

1.2.3 SOILS

Soils developing from sandstones and shales support the majority of the ponderosa pine stands. Englemann spruce and true fir timber stands are found in soils developing from igneous material or limestones at higher elevations. The soils are fertile and productive on the low slopes in the spruce-fir timber type area and in the rolling mesas underlain by sandstones in ponderosa pine zones.

The Alfisol and Mollisol soil groups comprise the majority of the soils on the forest. Rock outcrops are prevalent, especially in alpine areas.

1.2.4 CLIMATE

The San Juan National Forest has low relative humidity, abundant sunshine, cool summers with frequent showers, heavy winter snow and wide daily temperature fluctuations. Average annual precipitation varies from 38.1 to

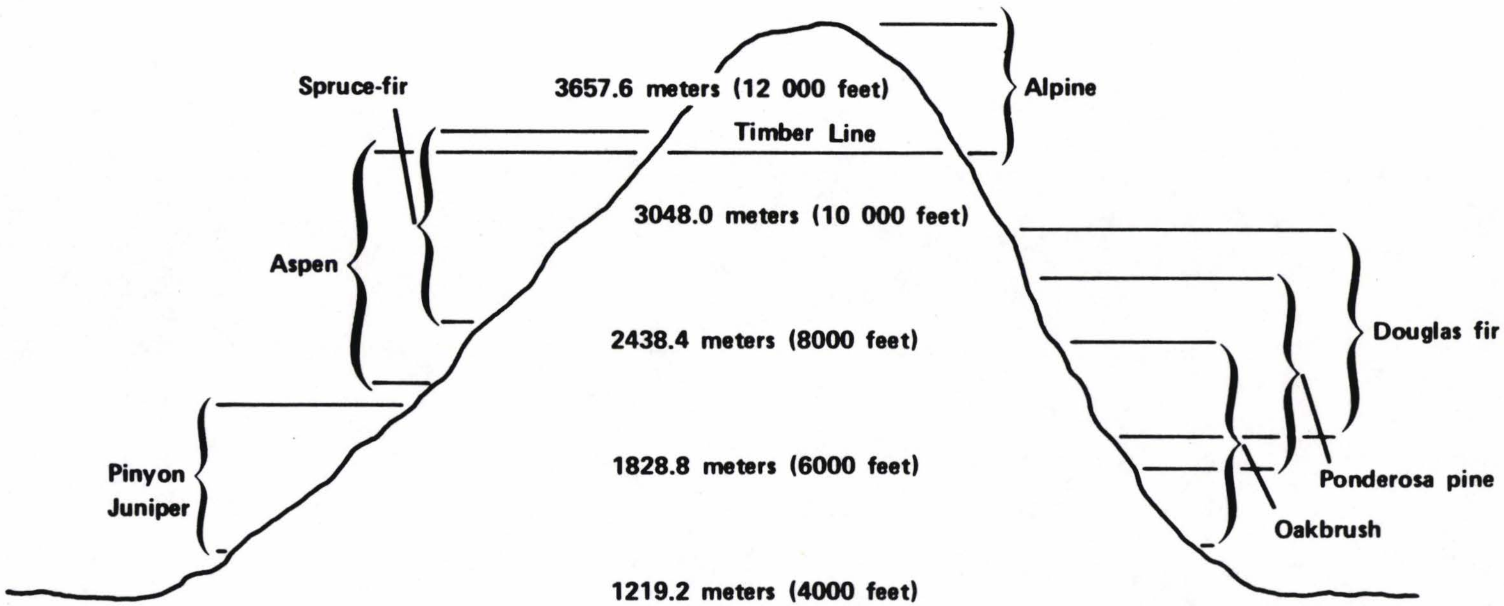

Figure 1-4.- Vegetation stratification by elevation and aspect on the San Juan National Forest.

152.4 cm (15 to 60 inches) with about 65 percent occurring as snow. Precipitation increases and temperature decreases rather uniformly with increases in elevation. Prevailing winds are from the southwest bringing most of the large storms in the area from off the southern California coast.

1.2.5 WILDLIFE

Within the forest, there are about 1,700 km (1,033 feet) of streams, 400 hectares (988 acres) of natural lakes primarily at the higher elevations and 1,300 km (3,212 acres) of impounded water. Fish, including brook, native, rainbow, and brown trout and Northern Pike are found in streams and lakes on the Forest.

Numerous mammals, birds, fish and reptiles inhabit the Forest. There are about 24,000 mule deer; 14,000 elk; 1,600 black bear; 200 bighorn sheep; 20 mountain goats; 60 mountain lions; and 1,100 turkeys in the Forest. The Forest also supports over 200 species of birds and 20 species of small animals.

1.2.6 RESPONSIBILITIES

The Forest Service is dedicated to multiple-use management of Forest resources for sustained yields of water, range, wildlife, timber, and recreation.

The Forest Supervisor is directly responsible to the Regional Forester for the management of the Forest. Four program officers direct the Supervisor's staff in four program areas. Program office responsibilities, program areas, and other staff in the Supervisor's office are shown in figure 1-5. There are five Ranger Districts on the San Juan National Forest. Each District has access to staff or staff expertise similar to that of the Forest Supervisor.

1.3 SAN JUAN NATIONAL FOREST MULTIRESOURCE PLANNING AND REMOTE SENSING PROJECT PROPOSAL

The San Juan Multiresource Remote Sensing Project is an operational demonstration of advanced remote sensing technology to supplement current methods of conducting and updating recurrent resource inventories and determining and monitoring change in the resources over the Forest and adjacent affected lands.

This project is viewed by the Forest as an opportunity to operationally implement what is learned from remote sensing research and development projects and as a means to apply some techniques to the solution of some very complex and time-critical problems.

The San Juan's commitment to the operational use of remote sensing technology to support land planning activities, resource management and monitoring of the results of management practices is unique in the Forest Service. Even limited achievement of the project proposal objectives would place the Forest and its Region in a favorable position of setting the pace

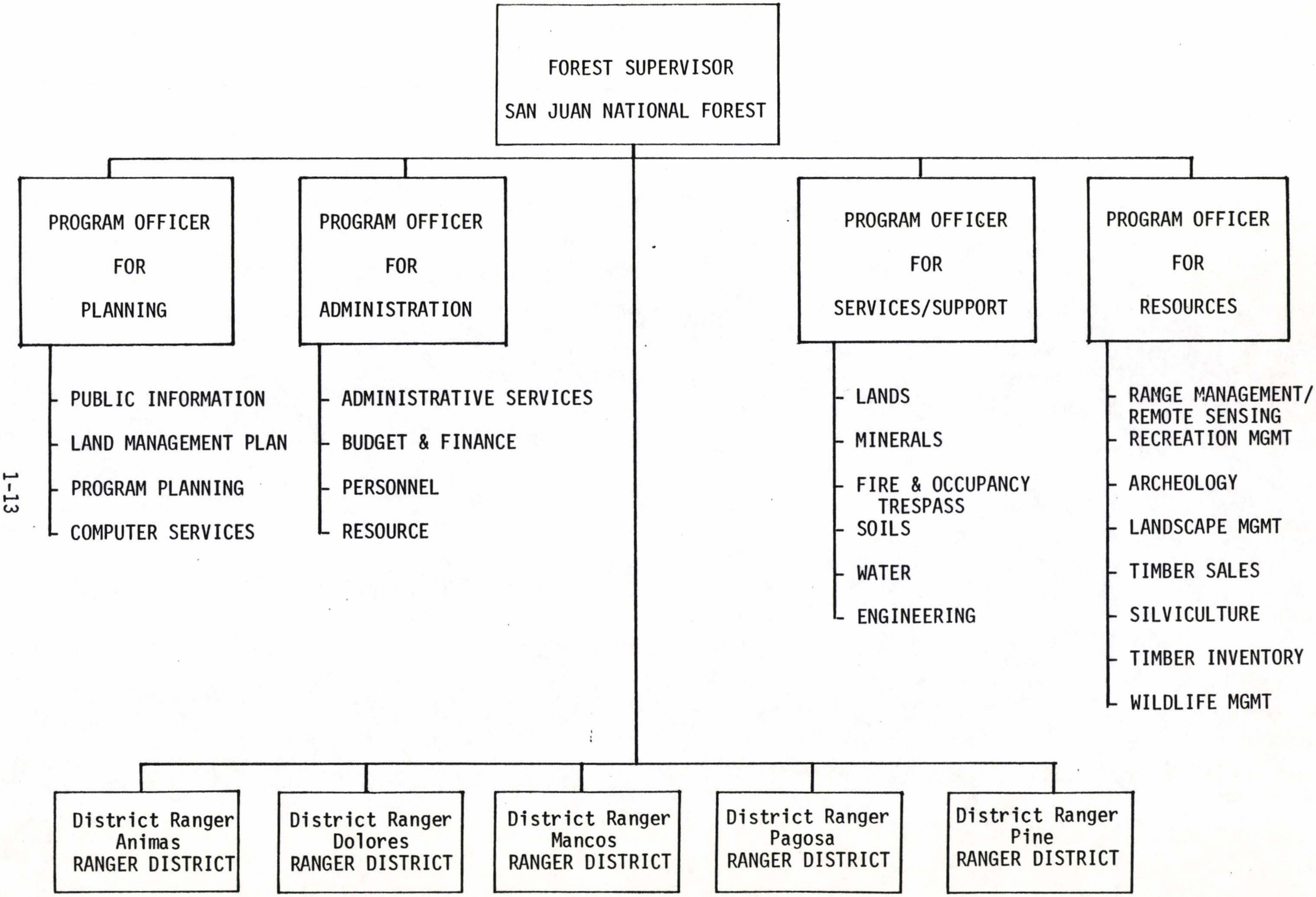

FIGURE 1-5 - SAN JUAN NATIONAL FOREST ORGANIZATION

for the rest of the National Forest System in responding to Regional and National Forest planning and management guidelines.

The objectives of the San Juan Multiresource Planning and Remote Sensing Project are to:

1. Evaluate the Landsat vegetation map data which presently exists as a layer in the Forest's R2MAP data base.
2. Operationally use remote sensing and related technology to
   a. develop and implement a computer-based forest resource data base;
   b. develop the capability for effective interaction with the forest resource data base to support forest program planning, budgeting, and decision making;
   c. develop and implement a capability to monitor change in the forest resource data base to determine attainment of forest plan goals and objectives.

Four tasks were developed from the above objectives to satisfy the project proposal which are:

Task 1: Evaluate the Landsat vegetation map data which presently exists as a layer on the Forest's R2MAP data base.

Task 2: Demonstrate procedures for using Landsat and large format camera data as a source for providing data to the forest data base.

Task 3: Demonstrate procedures for interactively manipulating a data base to produce new information needed for planning.

Task 4: Demonstrate procedures for updating the data base and monitoring progress in relation to the forest land management plan.

Task 4, a methodology to update, monitor and characterize change caused by and/or effected by the implementation of the forest plan was the primary objective of this report.

The general approach to attain this goal was:

- Establish a geographically-referenced digitized Forest data base in reference to day 1 of the forest plan.
- Establish digital image geographically referenced data base for the Forest.
- Test and evaluate the CVA/BLOB algorithm to detect and characterize the full spectrum of San Juan National Forest changes via the Remote Analysis Station (RAS) terminal.
- Utilize a RAS image terminal to support task accomplishment.
- Develop and test a dichotomous change key and analyst guide for San Juan National Forest changes.
- Test the change monitoring system for several select quad areas on the forest using 1978 and 1980 new mission data.
- Develop and test monitoring subsystem using **a priori** records information to train and direct the change monitoring system.
- Develop and test a technique for monitoring no change areas that should have changed.
- Evaluate the sensitivity of the change monitoring system to annual attainment of Forest land management plan (LMP) goals, objectives and/or targets.

2. BASIS OF THE STUDY

Monitoring change is an important aspect of land resource analysis and land management and therefore is involved in future tasks of the RRI Project. Changes in forest vegetation produces solar reflectance variation and consequently changes spectral densities on aerial photography and MSS data accordingly. Monitoring change is therefore feasible using aerial photography and repetitive earth observation satellite coverage. This data source for the current "mission image" (change data) and the corresponding "reference image" (baseline) is optimal for remotely sensing forest resource change.

The photointerpretive ability to detect and identify changes in forested areas can be improved by the use of interactive computer-based enhancement and measurement techniques. The process of manually searching both mission and reference images to find isolated areas of interest may seem time consuming and tedious. By incorporating an automatic means of isolating these areas, the computer can eliminate a good deal of tedium and can provide means for precise measurement and mathematical analysis of change events. Automatic change detection and monitoring is therefore an area of great potential in forest and range management as a means of isolating specific areas of interest and of reducing data. However, few operational studies have been conducted in this field and the minimum size of the areas that have been monitored is four hectares (10 acres). Automatic change detection is highly data dependent and the limits of what can be done are not yet defined.

2.1 OBJECTIVES

Any change detection and associated classification work in a forest area has four basic objectives which are to:

- detect what changes have occurred,
- identify the nature of these changes, which require a good knowledge of the area and of user needs,
- estimate the extent of the change, which requires at least to quantify the amount of change in areal extent (volume, density and vigor detection may be required for some changes), and
- specify the location of the change, which requires an output product referenced to a spatial location.

With the goal to initiate recommendations and basis for further change detection studies, two approaches were investigated:

1. Use of interactive computer-based enhancement and measurement techniques on DIADS for initiating recommendations for further detection of change on San Juan National Forest. Determine the capabilities of the DIADS for detecting changes and to develop and verify procedures utilizing DIADS.
2. Utilize the CVA/BLOB algorithm test in the study area, determine the algorithm's limits and develop a set of procedures to apply the CVA/BLOB algorithm on the San Juan National Forest.

Specific elements of interest for the forest manager were particularly investigated:

- site specificity,
- small area change detection,

- determination of helpful clues for change identification, and
- understanding of the problem of changes that cannot be detected and of "false alarm" changes.

2.2 STUDY PROGRESS AND CONTENT

In the first phase, the study site, dates and data were selected, not only on the basis of data quality and site interest but also on the basis of site knowledge and data availability, according to the short time available for the study and the DIADS software constraints.

A photointerpretation technique was developed for a systematic change detection of the study area using LFC high altitude CIR photography. The results were transferred to overlays on four 7-1/2 minute quadrangle maps of the study site. The areal extend for each change was measured. As no satisfactory classification systems or dichotomous change keys were available, elements for such a classification were brought by these first results and the creation of a dichotomous change key was attempted at the end of the study.

Phase two of this study consisted of selecting areas of the LFC photography to digitize. The digitized scenes were geometrically corrected for scene-to-scene registration. Various methods for detecting the different changes and identifying them using digitized LFC high altitude CIR photography with DIADS were investigated and the results analyzed for use with Landsat data in further studies.

No attempt to run the entire CVA/BLOB algorithm on San Juan was fulfilled but the results of the first two approaches and a good understanding of CVA/BLOB algorithm allowed some general recommendations, warnings and evaluations for its use on an area such as the San Juan National Forest. A field trip to check and refine the results of the study was taken in June, 1981.

2.3 SITE SELECTION AND DESCRIPTION

An area covered by four 7-1/2 minute quadrange maps (approximately 580 square kilometers or 160,000 acres) was chosen as it appeared large enough to provide a good range of changes and cover types and small enough to permit non-fastidious photointerpretation work.

According to San Juan National Forest interests four quadrangles were selected in the center of the Forest in the Mancos District (see figure 2-1). Several criteria governed study site selection. Many ground photographs were obtained to aid photointerpretation of the LFC high altitude CIR photographs by providing an overview of cover types associated with the study area. In addition, the NFA Program personnel offered a good working knowledge of this area because of previous association with this area. This same area has now been identified for further remote sensing studies in the Forest.

The major Forest cover type in the study site is aspen. Aspen is associated with interior ponderosa-pine, some pinyon-juniper in the lower elevations, and with Englemann spruce-subalpine fir and interior Douglas fir

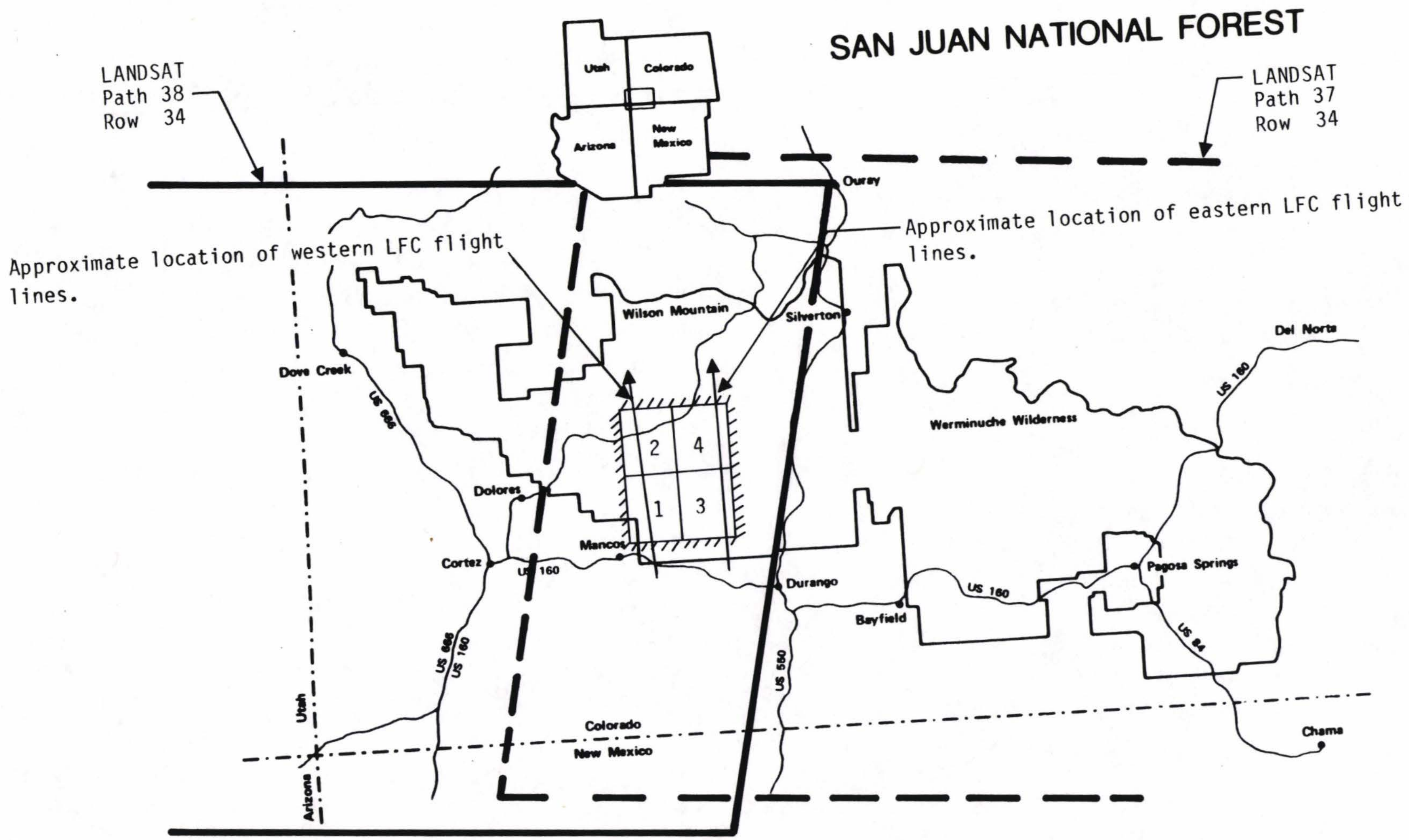

Figure 2-1.- Detailed vicinity map of the San Juan National Forest showing the four quadrangle study area: (1) Rampart Hills, (2) Wallace Ranch, (3) La Plata and (4) Orphan Butte. Also shown are the Landsat footprints and LFC flight lines.

at high elevations. The most common non-forested cover types are oakbrush and mountain meadows.

The aspen stands are widely developed between 2,300 to 3,200 meters (7,550 to 10,500 feet). Aspen type is usually seral and precedes the more tolerant spruce-fir forests but the rate of coniferous invasion is so slow that a virtual climax seems to have developed here and aspen vegetatively reproduces repeatedly and develops into all-aged stands. Regeneration from seed is rare and virtually all aspen stands have developed by coppice. As a result, stands are a mosaic of clones, each clone being made up of genetically identical trees. Trees within a clone develop and appear alike, but there is however a wide variation in characteristics between clones. Clones vary in size from a few trees on less than a hectare to thousands of stems on 20 hectares or more (Barnes 1975). The aspens are mostly found on southern aspects and in shallow soils on top of small buttes.

The more common secondary cover type after aspen is oakbrush which mingles and alternates with aspen stands and meadows at the lower elevations. Oakbrush occupies the same type of sites as aspens and is progressively replaced by aspen at higher elevations. Natural grasslands are more common at higher elevations. They are mostly wet meadows, small in size (except at the alpine zone), at the bottom of small valleys, and alternate with aspen and/or oak brush.

The pinyon-juniper is usually considered a forest type but in this study site is a woodland with trees shorter than 6 meters (20 feet) growing in dry, rocky and rough terrains under 2,500 meters (8,200 feet).

Pinyon-juniper temporarily gives way to grass or brush following disturbances, but shortly re-establishes itself and invades overgrazed areas. Some good stands of ponderosa pine are found at lower elevations (under 2,600 meters (or 8,500 feet) in relative flat areas or southern aspects.

Interior Douglas-fir grows on a wide variety of soils mostly on southern aspects, at elevations under 2,900 meters (9,500 feet).

Engelmann spruce-subalpine fir is considered to be at climax between 2,500 and 3,500 meters (8,200 and 11,500 feet). It is widely found at elevations higher than aspens on southern slopes.

2.4 DATA SELECTION AND ACQUISITION

Data acquired and used for this study included:

- LFC high altitude color infrared aerial photography,
- Landsat MSS data,
- 1:24,000 scale topographic maps,
- Forest maps for political and administrative boundary location,
- ground photography for photointerpreter training, and
- ancillary data of various types.

2.4.1 AERIAL PHOTOGRAPHY

Color infrared (CIR) aerial photographs acquired with a ACTRON HR-732 large format camera flown on NASA's U-2C aircraft at approximately 65,000 feet (19,800 meters) above sea level on August 19, 1978; September 21, 1978; and September 29, 1980 were available and duplicate transparencies were ordered and received in January, 1981.

The HR-732 sensor used a 609.6 mm (24 in.) focal length lens. High definition Aerochrome color infrared SO-127 film type was used for the 1978 acquisitions and a Aerochrome high definition color infrared SO-131 film was used for the 1980 mission.

The flight lines are shown in figure 2-1. The coverage was not total due to a holiday caused by elevation. The holiday between flight lines was 750 to 1,800 meters (2,500 to 6,000 feet) on the ground.

The average overlapping between frames was 60 to 70 percent in 1980 allowing a good stereo coverage and easy handling of the photographs. Overlap on the 1978 mission averaged 50 percent and some gaps in the steroscopic coverage occurred.

To cover an entire quad requires approximately three stereo pairs. Forty-eight frames were required to cover the study site. The quality of the photography was excellent for photointerpretation however some problems occurred due to the lack of contrast and color matching between acquisition dates.

2.4.2 LANDSAT IMAGERY

The criteria that directed the Landsat MSS data selection were:

- a Landsat acquisition date close to the high altitude photography acquisition date,
- acquisition date late enough in summer for snow coverage,
- similar dates between years for vegetation phenology and solar elevation similarities

- cloud coverage and image quality
- existing imagery in Region 2 or NFA Program offices

The study site is in the overlap area of adjacent Landsat scenes from two paths (see figure 2-1), two Landsat images were available from previous studies in the area.

Path 37, Row 34, July 3, 1978

Path 38, Row 34, August 28, 1976

As it appeared on EROS Data Center computer printout, only one image was available and therefore acquired for the summer of 1980 on the study site.

Path 38, Row 34, July 20, 1980

The overall cloud coverage for the 1980 scene was 10 percent and affected only a small area on the study site.

To perform a most recent possible change detection and to allow an accuracy assessment using large format camera high altitude photography, the 1980 image was selected as a mission image with the corresponding 1978 image as a reference image. Due to software restrictions on DIADS, the 1978 and 1976 data were used on the system as the mission and reference image respectively. The 1980 image ordered at EROS was used as a mission image for the CVA/BLOB algorithm test on San Juan.

2.4.3 TOPOGRAPHIC MAPS

Four topographic maps were ordered from USGS on a scale of 1:24,000. The map names were Rampart Hills, Wallace Ranch, LaPlata and Orphan Butte.

2.4.4 GROUND PHOTOGRAPHY

About 50 ground photographs of excellent quality showing various cover types in the study area in September, 1980 were available for ground truth and additional photographs of changed areas were acquired during the June, 1981 trip to the San Juan National Forest.

2.4.5 ANCILLARY DATA

Ancillary data were available from previous studies and were provided by NFA Program and San Juan National Forest personnel. The June, 1981 field trip provided the remaining needed information for the Forest vegetation and results analysis.

3. PHOTOINTERPETATION

3.1 GENERAL METHODOLOGY

The photointerpretation task was conducted in four steps:

1. systematic search of location of changes,
2. delineation of the changes on a grided overlay,
3. transfer delineations to maps, and
4. labeling and determining the areal extend of the changes.

A Richards light table with a Bausch and Lomb zoom 240 scanning stereoscope was used during the two first steps. A Richards stereo zoom transfer scope was used for step 3. The photographs used were laminated duplicate transparencies of frames:

158-170 and 352-365, Mission 80-158;

053-060, Mission 78-120; and

073-082, Mission 78-135.

The delineations were transferred to mylar overlays registered to 7-1/2 minute quadrangle maps.

3.1.1 SYSTEMATIC SEARCH

Several methodologies were investigated and a grid cell based interpretation seemed the only one applicable for a systematic search of the changes over a large area.

The grid size best suited for a simultaneous and quick view of every framed area, with sufficient magnification to record changes down to one acre, was

a 2 cm size grid. For size compatibility with the entire frame (9x18 inch), a .75 inch (~2 cm) size grid was selected which is approximately 570 x 570 meters on the ground or 32 hectares (1,875 x 1875 feet or 80 acres). The grid (24 x 12 squares) was drawn on 9x18 inch transparent overlay and each square was referenced by column and line number.

One overlay was taped to the light table under each objective of the stereoscope; the 1980 frames were successively, precisely overlayed and taped on one grid with the corresponding areas on the 1978 image on the other grid. The stereoscope was then settled in a manner that the same square number and area appeared on both dates.

The wall-to-wall change detection was performed by scanning the grid and comparing each framed area on both dates. The results were noted on a tally sheet and referenced by 1980 frame number, 1978 frame number, 1980 grid number and apparent change (see figure 3-1).

3.1.2 DELINEATION OF THE CHANGES

This step consisted of delineating the changes on grided overlays. The frames and grids were positioned in the same manner as in step 1 but with the grid laid over the 1980 frames. Using the first step results for locating the areas of interest, the changes were precisely delineated on the overlay. In some very hetergeneous areas a first delineation of the cover types in 1978 had to be drawn on a plain piece of acetate using a stereoscopic view. These polygons were then laid under the 1980 image and

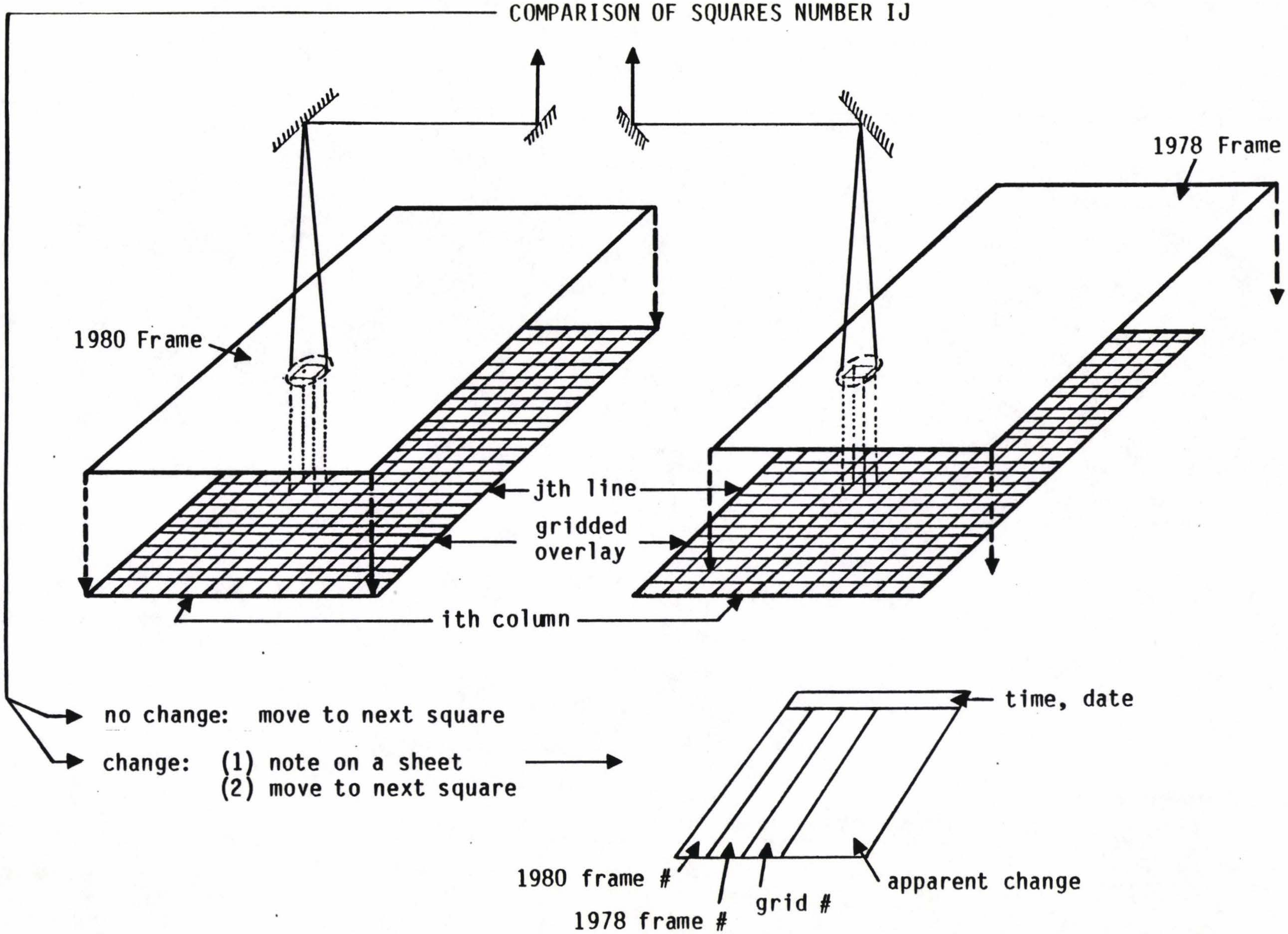

Figure 3-1.- Illustration of wall-to-wall systematic change search using LFC aerial photography and stereoscope.

so the change polygons could be drawn more accurately. The changed areas were preliminary labeled at this step. The resulting overlays were referenced with the 1980 corresponding frame numbers.

3.1.3 TRANSFER OF THE POLYGONS TO THE MAP

The stereoscopic 1980 pairs with their respective grided overlays were set over the light plate of the zoom transfer scope. The 1:24,000 scale maps with mylar overlays were set on the table. The polygons were then transferred onto the mylar map overlays, referenced to the quads. The approximate same scale of the images and of the maps facilitated this task.

3.1.4 LABELING AND AREA CALCULATION

Having a good idea of the range of changes in the area, a better and useful labeling could be attempted using the step 2 labels and a close stereoscopic observation of the changes. A definitive dichotomous change key could not be created before assessing the detectability of each change by other means.

A planimeter was used to estimate the areal extend of the changes.

3.2 RESULTS

An example of the end product is presented in figure 3-2 (map and change overlay). This cartographic product consists of the delineation of the changes, their areal extend and their type according to the framed classification for the study site. This classification (table 3-1) is not exhaustive; it is only based on the changes encountered in the study area and on the photointerpretation results.

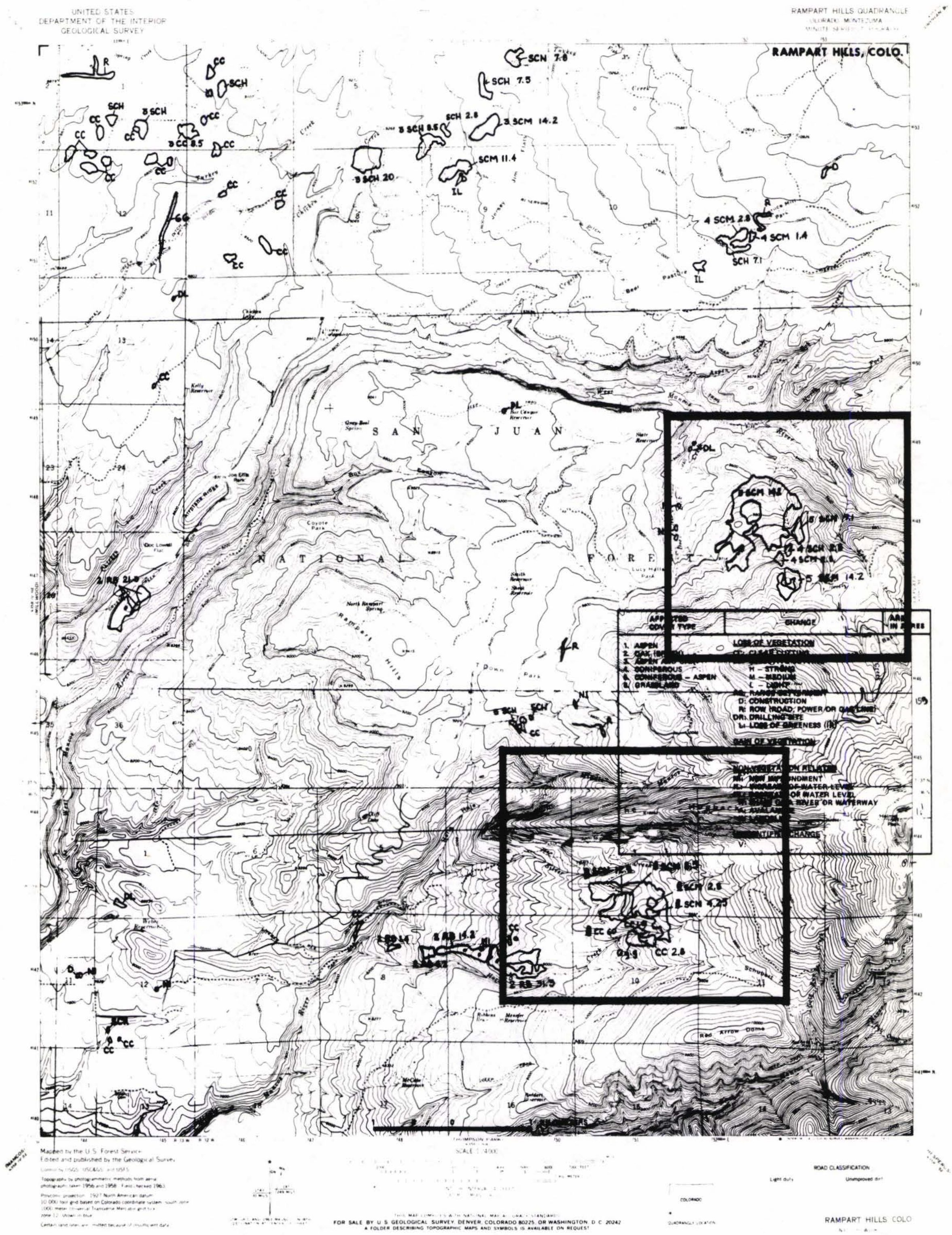

Figure 3-2.- Photointerpretation results transfered to the Rampart Hills Quadrangle. Also, note the DIADS study area outlined in black.

Table 3-1. Classification and Coding Scheme Used to Describe Changes in Land Cover as Interpreted from Multitemporal LFC Photography (e.g., 4SCL indicates light selective cutting in a coniferous cover type).

AFFECTED COVER TYPE	CHANGE	
1. Aspen	LOSS OF VEGETATION	
	CC:	Clear cut
2. Oak (Brush)	SC:	Selective cutting
		H - Strong
3. Aspen and Oak		M - Medium
		L - Light
4. Coniferous	RB:	Range betterment
	D:	Construction
5. Coniferous - Aspen	R:	R.O.W. (Road, Power Or Pipeline)
	DR:	Drill Site
6. Grassland	L:	Loss of Greennesss (IR)
	GRAIN OF VEGETATION	
	G:	Gain in Vegetation
	NON-VEGETATION RELATED	
	NI:	New Impoundment
	IL:	Increase in water level
	DL:	Decrease in water level
	W:	Change in shape of river or waterway
	A:	Avalanche
	K:	Landslide
	V:	Unidentified change

The changes always affected a homogeneous cover type and there has been no need to define various crown closure thresholds between affected cover types. The clear cuttings are defined as a total removal of timber. The selective cuttings are all partial cuttings or commercial cuttings with non total removal of timber. The range betterments are all land clearings of brushes. The new impoundments happened to be mostly beaver ponds.

Twelve 1980 frames were used for the entire coverage of the four quads. Out of these frames approximately 2,700 grid cells were examined in the first step. Out of the grid cells examined 139 grids were affected by a change (5.1%); the total time used for the first step was 95 hours. An average of 40-50 minutes per frame was thus spent on initial examination. Ten to fifteen seconds per grid cell allows ample time for a good examination of the area and permits detection of very small changes.
The second step took about six (6) hours and transfer to the map took an additional six hours. Once the change labeling scheme was selected, step 4 took about five hours. The time needed for the three last steps greatly depends on the amount of changes and thus an average time cannot be evaluated.

3.3 COMMENTS

Although systematic change detection using photointerpretation techniques seemed **a priori** fastidious - only 3 to 8 hours (depending on the amount of changes in the area) were needed for detecting and characterizing the changes in a quadrangle sheet size area (16,000 hectares or 40,000 acres). Nevertheless, such results can be attained only if the photointerpreter rigorously follows a well organized predefined methodology.

The minimum change size detected (one acre) goes beyond the needs of the Forest. Most of the changes directly related to a human mechanical activity could be detected as small as 1/5 acre.

According to the District records, one light cutting remained undetected north of the Rampart Hills quad.

Two labels created some problems at the District level: clear cutting and range betterment. In the San Juan National Forest, an area affected by a timber sale is considered a commercial clear cut even though the buyer only did a partial cutting of the timber stand for commercial purposes. Most of the labeled selective cuttings area were thus considered as clear cuttings by the District personnel. Some other selective cutting areas were in fact in the process of being clear cut. The areas labeled range betterment were all land clearings but may well have been for wildlife habitat improvement. Those objectives could hardly be assessed by photointerpretation techniques without preliminary site and timber practices familiarization. Those remarks were taken in account for the creation of the dichotomous change key.

No attempt has been made to do a delineation and location accuracy assessment because the precision of the results seemed better than needed and no data but perhaps large scale photographs could have been used for this task.

These satisfactory results must leave aside some problems linked with the data and its acquisitions; the most important being the color difference between the photographs acquired in two different dates. Even with the same type of film camera and the lack of calibration between the two mission acquisitions resulted in an overall color difference in the original films. The color differences were quanitified using DIADS, the three basic color variations were:

- blue color: in a total range of 90 density values, the blue color in 1980 was 5 density values over the blue color in 1978 (+ 5.5%)
- green color: in a total range of 110 density values, the green color in 1980 was 27 density values over the green color in 1978 (+ 25%)
- red color: in a total range of 100 density values, the red color in 1980 was 10 density values over the red color in 1978 (+ 10%)

The overall low green density in the 1978 film resulted in a low contrast, very red image compared with the 1980 mission. With such data, changes resulting mainly in a reflectance variation were difficult to detect. Such changes as stresses in vegetation, regrowth or regeneration could not be detected with certitude or delineated with confidence. In many cases it was difficult to decide whether or not there had any regeneration (or stress) in a certain area and a subjective decision was made. The difficulty to delineate those changes was enhanced by the fact that they were often non human activity related and thus, didn't have a defined pattern nor a distinct boundary.

The phenology difference between the two sets of data was due to the difference in acquisition dates. The vegetation changed earlier in 1980 than in 1978. The main concern were the aspens, which grow in very homogeneous clones that may have very different characteristics between one another. Nearly half of the clones began senescence in the 1980 images but were still hardy in the 1978 images. Those clones were not to be detected and enhanced the problems of stress detection.

Less important problems were encountered with the sun elevation during the image acquisition. In the eastern track (sharp relief) shadows were prevalent on the steep slopes where erosion is the more likely to occur thus preventing the detection of such events if any.

As a conclusion for the quality of the photographic product, it can be stated that the format of the photographs was very handy for this task and the scale and resolution were very satisfactory, but the calibration problem between data acquisitions was a big constraint for detecting changes. Cost considerations make such a calibration unfeasible.

3.4 RECOMMENDATIONS

All time spent for organizing the photointerpretation work, selecting the best combination of frames and suppresssing the overlap areas and outline of study site areas greatly facilitates and accelerates the photointerpretation work.

In a forest similar to the San Juan National Forest, the minimum size requirement seems to be close to three acres. According to the results in the minimum change size detected, a smaller magnification associated with a larger grid should be used. This would diminish the time spent on the first step proportionally and the work will be even less fastidious.

The overall color difference could be diminished by using different filters during the duplication. The filters should be selected by matching the colors in areas that have not changed.

The mission image acquisition date should be selected not only in relation to the reference image acquisition date but also in relation to the vegetation phenology stage in the area of interest. This is particularly important in a mountainous area like San Juan National Forest where the climatic conditions may greatly vary from one year to the other in transitional seasons. This would be specially interesting for species like the aspens but would require a good flexibility in flight planning. The acquisition dates must also be selected according to the field work periods in the Forest.

For steps 1 and 2, a capability of switching the view between images, other than by blinking eyes, would greatly facilitate the work. This could be performed by setting independent foot switches for each light table.
Also, for steps 1 and 2, the capability of having a stereoscopic view for both dates would ameliorate the results but this not only would require more handling of photographs but would also require very sophisticated tool necessitated by the scanning.

4. DIGITAL IMAGE ANALYSIS AND DISPLAY SYSTEM (DIADS) APPROACH

Digital data from two sources formed the image data base used in the DIADS-assisted approach to detecting and analyzing change. First, available Landsat computer compatible tapes were read into DIADS memory storage followed by transferring information digitized from select areas on LFC altitude photographs into DIADS memory.

Image enhancements and other digital approaches were used for assessing the detectability of changes. Procedures and recommendations were developed for change detection in the San Juan National Forest using digital data. The overall utility and capabilities of DIADS were assessed according to those results.

Although a correlation between the digitized infrared high altitude photography and the Landsat imagery cannot be made directly, the digitized photography was used in this task because of the ground truth availability through the photointerpretation results. Through the various tables presented in this section, the results from digitized high altitude photography provides real indications for the detection of changes using Landsat data.

4.1 DIADS DESCRIPTION

The Digital Image Analysis and Display System (DIADS) is a digital image processing system as implied by its name. Emphasis in its current configuration is on display and analysis of imagery and image-like data.

Input/output devices and interactive processing software allow interaction between the user and the digital data set.

The functional diagram of DIADS is provided in figure 4-1 and the hardware configuration is presented in figure 4-2. Each DIADS hardware component is described in the following subsections.

4.1.1 PDS 1010A

The PDS 1010A flatbed microdensitometer has three major components: (1) an imaging system to measure film density/transmission or to expose film for recording; (2) a servo-motor system to move the stage independently in perpendicular directions; and (3) a precision read out system for stage positioning.

The film input (color, black and white, positive or negative) can be in any format up to 14x14 cm (5.5 x 5.5 inch). The output product from the PDS 1010A is a digitized image.

4.1.2 COMTAL IMAGE DISPLAY SYSTEM

The Comtal has three major system components: a digital disk unit storage of three digital images of 512x512 points, 8 bits each (0.79 megabytes total); solid state tables; controls and a television monitor.

Each Comtal image is stored on one of three bands on the Comtal disk system. Each band has its own function memory which is a solid state memory of 256 registers for mapping an input value to a particular brightness value. Output from any function memory can be routed to either one of

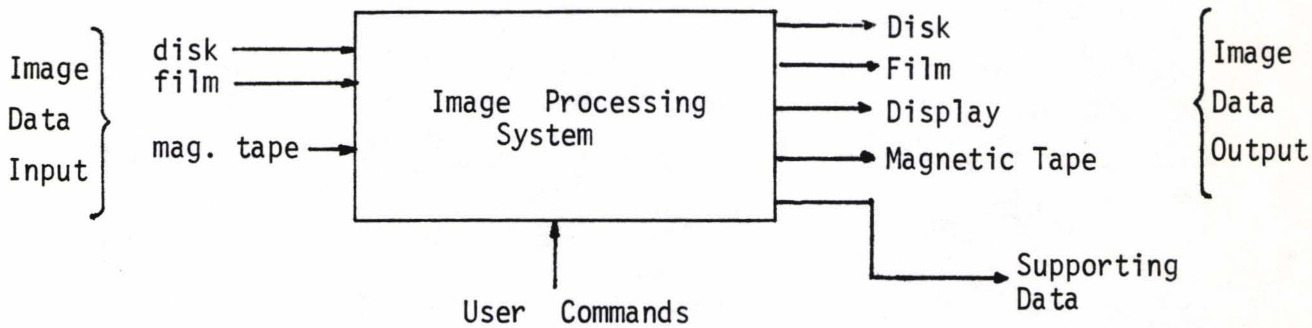

FIGURE 4-1 - FUNCTIONAL DIAGRAM OF DIAD SYSTEM

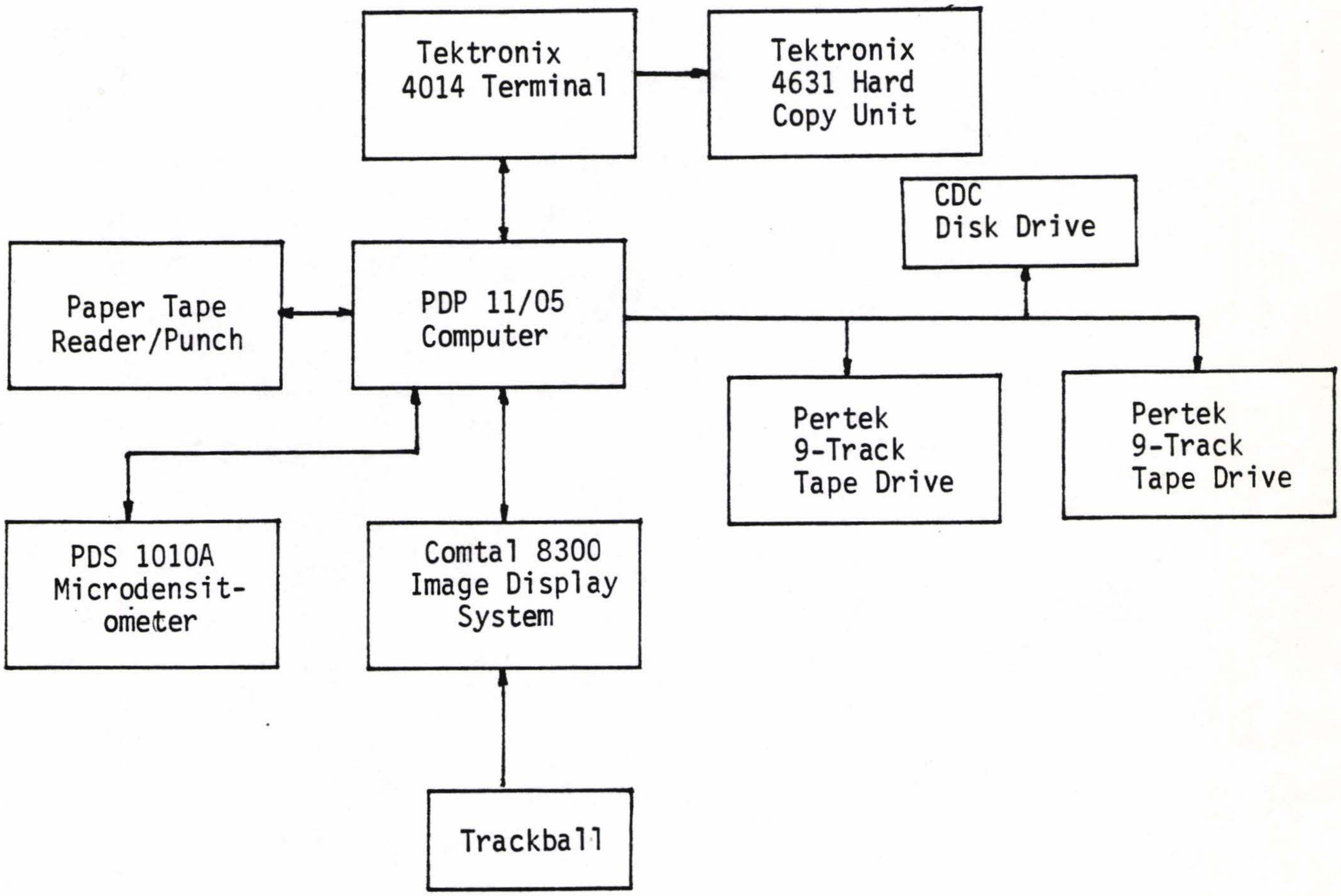

FIGURE 4-2 - SCHEMATIC DIAGRAM OF DIADS HARDWARE AND ITS CONFIGURATION

the three display monitor color guns or to a single pseudo-color function memory. The pseudo-color function memory translates the upper 6 bits of the input to a triad of 4-bit output values, one for each color gun. The Comtal system, including all function memories, is designed to refresh the display at 30 full 512x512 frames per second.

In addition, the Comtal system has three overlay channels (512 by one bit images) that may be used for annotations and/or graphics. The Comtal system also utilizes a trackball unit with a programmable cursor. This trackball unit is one means to enter information (commands), the other being the terminal board.

Comtal hardware capabilities provide the basis for numerous interactive functions of image analysis, enhancements, comparisons, and a means for interactive input of commands.

4.1.3 PDP 11/05 COMPUTER

The DEC computer has 28K bytes of memory and is completely dedicated. It performs four basic functions:

- interface to the user,
- control of other system components,
- processing, and
- data management

The software operating system is a foreground/background type on which the user can perform interactive programming in the foreground simultaneously with execution of processing functions in the background. The computer has

been programmed in the highly interactive FORTH language. The DIAD System also operates under the FORTH operating system.

4.1.4 PERTEK 9-TRACK 800 BPI TAPE DRIVES AND CDC 80 MEGABYTE DISK UNIT

The tape drives serve as input/output and storage devices for image data and software. Some supporting data (image parameters, control points, coordinates, etc.) may be stored as a header record for the corresponding image file on tape. Image data must be on a standard format. The disk is the prime storage medium for software with tape as a backup. Digitized images of 512x512 x 8 x 3 colors can be stored on disk for interactive work.

4.1.5 TEKTRONIX 4104 TERMINAL AND 4631 HARD COPY UNIT

The primary role of the Tektronix terminal is input of user commands and display of messages generated by the system. It also provides the means for display annotations, graphics and other such one-bit information. For the 4014 terminal, the Tektronix 4631 is the sole source of hard copy output from the system.

4.2 COMPUTER FAMILIARIZATION

Various readings for understanding DIADS components and functions as well as learning the FORTH programming language for understanding the basic software were conducted in January and February.

The set up of the computer and loading of newly written software was completed by mid-February.

Computer familiarization then consisted of working on demonstration images with the basic commands, testing various new commands, correcting some software and adapting and creating some programs for support on this study.

Most of the familiarization was done by trying to understand software problems and inputing various data (LFC or Landsat). The computer familiarization, basic software understanding and corrections were very time consuming because user manuals were out of date and some programs had been added or modified during the last few years without being documented. Some of those changes had not been tested thus creating problems and errors during the initial runs.

The most concerning software problem was the input data format restrictions. The only format that can be read on DIADS is the GSFC "A" format which has not been produced by EROS since 1978. No software was available for changing the 1980 "P" formatted tape to the "X" format needed by the system and it was decided it would be too long to develop this software during the study. Thus only a 1976 to 1978 change detection using two available tapes could be attempted using the results and information acquired with the analyse of digitized LFC photography.

4.3 GENERAL METHODOLOGY

The major steps of the DIADS phase of this study were:

- digitization of the study site on the 1978 and 1980 LFC photographs
- image-to-image registration of the study site
- obtaining density measurements on various cover types
- color matching of the images

- creation of a false color change image
- delineation of the changes, labeling and area calculation on the false color change image
- subtraction of various combinations of bands between dates
- setting of various thresholds for detecting changes
- conclusions on the detectability of each change - understanding of the problems of "false alarm" and undetected changes
- evaluation of those results for use with Landsat data
- change detection on Landsat data using the same procedures
- conclusions on DIADS

4.4 DATA INPUT AND IMAGE-TO-IMAGE REGISTRATION

The two framed study areas seen on figure 3-2 were selected for the digitization of the photographs. Both date photographs were successively digitized using the red, blue and green filters to allow density readings in each of the three primary colors.

Since the maximum image size handled by the disk and the Comtal is 512x512 pixels, it was decided that only images filling a 512x512 area would be digitized. The maximum aperture available on the microdensitometer is 50x50μm and thus, a wall-to-wall digitization would lead to a data overflow. A 250μm spacing was chosen in combination with the 50x50μm aperture to scan the largest possible area. The resulting image size scanned was thus 12.8 x 12.8 cm on the photography, equivalent to 3.8 x 3.8 km on the ground with a 56 square meter IFOV. Because of the calibration of the

microdensitometer, it was desirable for all digitizations to be accomplished in one day. The range of measured densities on the two sites is presented in table 4-1.

TABLE 4-1. The minimum and maximum image density values obtained from the PDS 1010A microdensitometer are presented. Maximum range of densities - 0-256.

		BLUE		GREEN		RED	
STUDY SITE	DATE	MIN	MAX	MIN	MAX	MIN	MAX
NORTHERN	1978	117	181	116	212	149	233
	1980	130	190	150	244	165	250
SOUTHERN	1978	118	184	120	213	161	243
	1980	117	192	138	246	136	249

Two problems arose during the image-to-image registration. First was the difficulty to locate an area on a transparent photograph once it is mounted on the PDS 1010A microdensitometer. Secondly, the variations in location and altitude of the aircraft between acquisition dates of photography.

On each area, 15 to 20 control point locations (in x, y coordinates) were recorded on both dates using the cursor. Linear regressions between x and y and between y and x were performed for determining the needed corrections.

Neither rotation software nor linear interpolation software were available. Geometric corrections performed were origin displacements and image rotations. Geometric reductions and enlargements were approximated by deleting

or duplicating regularly spaced lines and/or columns of pixels. To approximate the rotations, horizontal and/or vertical strips were successively shifted based on the linear model. Although these geometric correction procedures seemed very rough, the visual quality of the registration was good enough for work to be done with no additional software.

During this phase, two problems were noted:

(1) the poor quality of the Comtal screen does not facilitate an accurate location of the control points, and

(2) the geometric operations are performed only at a precision of two pixels even if the parameters are set to a one pixel precision.

4.5 FALSE COLOR CHANGE IMAGE

Measures of the standard deviations of pixels density and of average pixel density over identical areas on the two dates were performed for various cover types. Fifteen areas were selected on the first set of images and eight on the second. The averaged results of the densities per cover type are shown in table 4-2.

Using the results of the measurements in unchanged areas for calculating density variations between dates, the color was matched and image quality enhanced by color stretching.

TABLE 4-2. Average density values per color per date are shown along with the magnitude of range between the cover types listed.

Cover Type	Color B=Blue G=Green R=Red	Average 1978 Density Value	Average 1980 Density Value	Magnitude of Average Density Change 1980 - 1978
Clear Cutting (Aspens)	B	150	164	+14
	G	155	206	+51
	R	213	213	0
Land Clearing	B	152	159	+ 7
	G	158	194	+36
	R	216	208	- 8
Aspens	B	149	152	+ 3
	G	155	180	+25
	R	213	222	+ 9
Aspens Faded in 1980	B	150	159	+ 9
	G	156	195	+39
	R	211	221	+10
Grassland	B	165	168	+ 3
	G	182	207	+25
	R	204	216	+12
Oak Brushes	B	156	158	+ 2
	G	166	191	+25
	R	215	217	+ 2
Conifers	B	145	152	+ 7
	G	147	172	+25
	R	185	196	+11
Selective Cutting (Aspen/Mixed)	B	151/149	158/162	+ 7/+13
	G	156/154	193/197	+37/+43
	R	206/201	208/214	+ 2/+13

4.5.1 MATCHING OF THE COLORS

As previously stated (section 3.3), the density variations between dates were found to be:

Blue: +5 Green: +27 Red: +10

For color matching, 5, 27 and 10 brightness values of the 1978 data were subtracted from the blue, green and red images respectively of the 1980 data.

4.5.2 CREATION OF THE IMAGE

Using the matchings described in section 4.5.1, a good false color change image was created. The best result was obtained by displaying the green image 1980 in the green gun, the green image 1978 in the blue gun and the red image 1980 in the red gun. Hence, the green image seems the best channel for detecting land cover changes with this method.

In this false color image, the areas that appeared green (or yellowish-green) were areas which naturally reflect more in the red part of the spectrum in 1980 than in 1978. The areas that appeared blue or magenta are those areas which reflect less in the red part of the spectrum in 1980 than in 1978.

The apparent changed areas were delineated, labeled and measured using the cursor and the overlay channels. The results when compared to the photointerpretation method for one of the two digitized areas are presented in table 4-3.

TABLE 4-3. Areal Comparison of a Computer-Assisted Interpretation to a Photointerpretation of the Same Area

TYPE OF CHANGE	COMPUTER-ASSISTED INTERPRETATION (ha)	PHOTOINTERPRETATION (ha)
Clear Cut Area	22.6	24.2
Land Clearing	7.9	8.6
Regeneration	5.7	4.0
Selective Cutting	10.8	11.5

4.5.3 CONCLUSIONS

The multidate image appears to be a very useful product for assessing the changes in a forested area. This product allows the user to look for changes on only one image hence the user is able to use this interpretation capability. The color matching permitted the user to delineate regrowth areas more confidently than with the photointerpretation method. The patterns and structure of each area help in differencing changes like clear cuts from faded aspens and from land clearings even if the color differences are unnoticeable.

4.6 DETECTION OF THE CHANGES BY AUTOMATIC TECHNIQUES

The capability of detecting and identifying a change by automatic data processing is a function of the amount of spectral change. Those spectral changes were therefore measured for each cover type, whether or not affected by a real change, and are presented in table 4-4. Table 4-4 was a very useful tool for assessing the capability of isolating change areas and thus orienting the selection of various combinations of bands in the change detection methods investigated.

TABLE 4-4. DATA SHEET SHOWING SPECTRAL CHANGES FOR VARIOUS COVER TYPES USED IN THE DIFFERENCING ROUTINE

Standard Deviation 78

Standard Deviation 80

Density 80 - Density 78

	BLUE			GREEN			RED		
	Standard Deviation 78	Standard Deviation 80	Density 80 - Density 78	Standard Deviation 78	Standard Deviation 80	Density 80 - Density 78	Standard Deviation 78	Standard Deviation 80	Density 80 - Density 78
CLEAR-CUTTINGS	3	5	9	5	6	24	10	9	-10
SELECTIVE CUTTINGS HARDWOOD/SOFTWOOD	12/4	6/6	2/8	9/6	14/12	10/16	5/10	12/11	-8/3
LAND CLEARINGS	3	2	2	6	3	9	7	3	-18
ASPENS	3	5	(0, 12)	5	8	(-2, 13)	8	10	(-2, 7)
GRASSLANDS	2	2	(-2, 2)	3	3	(2, 8)	3	3	(1, 2)
OAKBRUSH	6	5	-3	11	11	-2	10	11	-8
CONIFEROUS	4	4	(-3, 2)	6	8	(-9, 0)	9	11	(-10, 1)
REGENERATION	5	5	-1	9	10	7	9	5	1

4.6.1 PROCEDURE

The automatic technique of change detection consisted of subtracting one band or combination of bands on the mission image from the same band or combination of bands of the reference image, thus creating a difference image.

A histogram of the difference image takes on the characteristics of a spike. By developing thresholds of the histogram selected desired areas (changes) can be displayed.

The selection of bands and combination of bands to be used in the differencing routine was determined by means of table 4-4. The standard deviation threshold analysis was conducted using the resulting overlays of the false color change image as a ground truth. The best thresholds were selected by interactively trying to match the areas whose pixel values lied beyond the threshold (in number of standard deviations) to the overlay.

Each change or combination of change was measured by counting the number of pixels whose values were beyond the selected threshold.

The accuracy was visually assessed and the acreage compared with the photo-interpretation and false color change image results.

4.6.2 RESULTS

The level of registration combined with the high variance of the densities with this ground resolution gave the difference image a salt-and-pepper appearance. A cell averaging was done to eliminate this problem. The best averaging was a 6x6 cell averaging.

As expected when considering table 4-4, the best combination of bands were:

- the green alone for separating change from no change
- the red for separating land clearings from the rest (a part of the clear cutting was also apparent)
- the blue for separating clear cutting and part of the selective cutting from the rest
- the red-green-blue for separating clear cuttings and land clearings from the rest

The major results are presented in tables 4-5 and 4-6.

TABLE 4-5. Change Results Associated with the Thresholding Method

Combination of Bands*	Changes Displayed	Threshold in S.D.	Area
R	Land Clearing; few clear cuttings	+ 2.05	13.0 ha
G	Clear Cutting	- 2.25	31.9 ha
	Land Clearing Selective Cutting (Majority), Good Part of the Aspens		
B	Clear Cutting Few Others	- 2.5	23.9 ha
R-B	Clear Cutting Land Clearings Few Selective Cuttings	+ 2	30.0 ha
R-G	Clear Cutting Land Clearings Few Selective Cuttings	- 2.5	28.2 ha
R-G-B	Clear Cutting Land Clearings Very Few Others	- 2.8	32.0 ha

* R = Red, G = Green, B = Blue

TABLE 4-6. Areal Comparison of Photointerpretation and DIADS Thresholding Technique over the Same Area.

Landcover Change	Photointerpretation (ha)	Threshold Technique (ha)	Difference Image Used
Clear cut	24.2	23.9	Blue
Land Clearing	8.6	8.1	R-G-B&B

4.6.3 COMMENTS

Natural variations in the spectral signature of aspen are difficult to separate from real change. Due to the variation of phenologic stage between clones at any point in the growing season and between dates, the range of spectral changes in the aspens is very large and therefore commission errors occur within a narrow range of threshold values. Thus, only clear cut areas and land clearings could be readily isolated. The green display channel was the best for separating any vegetation change (vegetation removal or phenologic change).

The partially cut areas had a spectral variation halfway between clear cuttings and no change and thus were mixed with aspens. For those partial cuttings, the high resolution caused additional problems, even with cell averaging, related to the heterogeneity of spectral variations. For detecting and identifying selective cuttings, a lower resolution would be more appropriate. In the case of a coarse resolution, a clustering and stripping would also be helpful for those areas because of the problems of mixed pixels (forest - clear cuttings) that have a similar spectral response to the partial cuttings.

No regeneration was identifiable because the regeneration class overlapped with the grasslands within less than 0.5 standard deviation.

4.7 EXTENSION TO LANDSAT DATA

The results of the study using digitized photography were applied to the detection of changes using Landsat data. Due to format problems the change

detection was performed between 1976 and 1978 instead of between 1980-1978. No ground truth was available except for some District records.

The two Landsat images were acquired from two different Landsat paths but comprised the study site in their overlap area. The image-to-image registration was conducted in the manner as with the digitized photographs. Due to the difference in the location of the spacecraft during image acquisitions, the registration was poor. As no ground truth was available for these dates, the study area was moved west where less snow and smoother terrain was present without losing information. The area studied, after geometric corrections, was about 480x480 pixels and approximately encompassed the area of four quad sheets (Rampart Hills, Wallace Ranch, Millwood and Stoner).

4.7.1 RESULTS

The false color change image did not produce favorable results because of the poor registration, the low variation between pixel values in vegetated areas and the type of changes that had occurred in the study site. A false color change image with good registration was created by ERIM in June with 1978 and 1980 data. The burned areas could easily be identified and located in this image, as well as the large clearings, but the changes of smaller size which occurred in the study site were barely discernable.

However, this product was very useful during the field trip for orientation in the field and subjective ground truth for implementing an automatic change detection.

Subtraction of various bands or combination of bands was also attempted, followed by a thresholding of the image. Band 5 and band 7 minus band 5 (vegetative index) gave the best results.

The variation in snow coverage was very easily detectable with the vegetative index. All values beyond +1.35 standard deviations from the mean were areas with snow cover in 1978 and no snow in 1976. Between +1 and +1.35 standard deviation from the mean the other decreases in vegatation appeared. This was verified by examining the Mancos District records. A lot of commission errors appeared, due mainly to misregistrations (bottom of the valleys and top of the mountains).

A few pixels (100) were beyond - 2.5 standard deviation from the mean, in two isolated areas and probably showed regrowth of vegetation.

4.7.2 COMMENTS

The lack of adequate image-to-image and image-to-map registration as well as the lack of suited data and ground truth greatly diminished the quality of information provided during part of the study. No change detection using DIADS should be attempted using two images acquired on two different Landsat paths.

The San Juan National Forest has a very heterogeneous vegetation cover creating a lot of mixed pixels and most of the changes are small in size (in the study site, maximum 60 acres for clear cuttings, 15 acres for land clearings, 200 acres for selective cuttings, but most often in the order of

10 acres). These characteristics make it difficult to perform a pixel by pixel change detection.

No accuracy assessment for the areal extend or the location of the changes was attempted because of the lack of image-to-ground registration and the lack of accurate ground truth.

MSS band 5 and the vegetation index (Band 7 - Band 5) were the best channels for detecting the vegetation changes and thus confirmed the results of section 4.6.

The Landsat images were acquired earlier in the summer than the high altitude photography, thus less problems occurred with the aspens but almost no change could be detected for the mission image year.

A simulation of the Landsat spatial resolution using digitized photography was attempted by replacing 8x8 LFC pixels by one pixel with their averaged density values. Using the techniques discussed in section 4.6 the clear cuttings and land clearings were easily detectable but the test threshold settings were difficult to assess.

4.8 EVALUATION OF DIADS USE FOR DETECTING CHANGES IN A FOREST AREA

The use of interactive computer-based enhancement and measurement techniques on DIADS required substantial training since the software is not "user friendly" to scientists unfamiliar with FORTH language. Additional time was required for dealing with software problems as can be seen in table 4-7.

TABLE 4-7. Summary of Additional Time Necessary to Perform Various Interactive Image Analysis Functions on DIADS

CATEGORY	TASK TO BE PERFORMED	TIME (HOURS)
Training	Readings	15
	Demonstration Images Manipulation	60
	FORTH Language & Basic Software Understanding	30
Software	Testing of Newly Written Software	15
	Resolving of the Landsat Tape Reading Problem	10
	Image Subtraction Software	20
	Other Problems (backup, etc.)	40
Data Input	Site Extraction from Landsat Tapes	4
	HAP Digitization	15
Proceedings	Geometric Corrections (HAP and Landsat)	20
	Color Calibrations	5
	Averagings, Combination of Bands, Subtraction, etc.	100

Numerous hardware and software problems were encountered during the progress of the change detection study. These need to be enumerated for a better understanding of the recommendations.

4.8.1 HARDWARE RELATED PROBLEMS

- The microdensitometry is very time consuming with the PDS. Twenty-five minutes were needed for scanning each selected area with one filter.
- The area to be digitized is almost impossible to locate on a film because there is no backlight on the PDS plate.
- The visual procedures for calibrating the PDS are no longer applicable. Many runs (trial and error) are needed before selecting the correct calibration.
- The difference in spectral transmittance between filters of the PDS may be a nuisance for the color calibrations.
- The Comtal display screen is of poor quality. The image flickers. Three colors are impossible to register to one another on the full screen. (For accurately locating the control points, the best thing to do is to work with a black cursor on a one color image.)
- The 512x512 image limitation of the Comtal is a big constraint if DIADS is to be used in a production mode. The limitation to three images handling by the Comtal may also be a constraint.
- Any processing of data (subtraction, averaging) is very time consuming.
- No effective output device for image data is available.
- No digitizing table for registrations is available.

4.8.2 SOFTWARE RELATED PROBLEMS

- A lot of program errors appeared in the software.
- The source language is not user oriented.
- The Landsat tape format is restricted to the old "X" format.
- No geometric correction and registration software is available.
- No clustering algorithms are available.
- The software is oriented toward manipulation of the display but not toward manipulation of the data.

In spite of those constraints, the major constraints were the lack of registration and the Landsat format compatability, DIADS proved to be a good tool for this change detection study. By its interactive enhancement and

calibration capabilities, it permitted to improve the ability to detect, delineate and measure changes. Its measurment capabilities allow the user to understand the various problems related to the various cover type reflectances and thus to assess the detectability of the changes for a further change detection study.

Thus, it can be stated that the system may be useful for conducting feasibility studies and supporting investigations for guiding any further digital approach of change detection on a specific area. But even for such a restricted use, some of the above mentioned problems should be resolved.

4.8.3 RECOMMENDATIONS

Before any further use of DIADS, most of the software should be revised to avoid any additional waste of time in correcting it during operational use. All software needs to be well documented and the vocabulary list and menu updated. In case of a later use as a multi-user system, a more user-oriented language should be created (menu-driven).

New software should provide for the capability of creating a new image with enhanced values (stretching of the colors, calibration, etc.), capability of geometrically correcting the iamges with linear interpolation and capability of clustering an image. This could be done without changing or adding any component to the system.

Unless the system is only oriented toward the use of digitized photographs, the software should be made compatible with all Landsat tape formats. The lack of image data output, the 512x512 images constraint, the problems related to the digitizing scanner (size, time), the lack of means to register any product to a map are some of the elements that seem to prevent the system to be used in a production mode.

5. FURTHER CHANGE DETECTION ON THE SAN JUAN NATIONAL FOREST

5.1 DICHOTOMOUS CHANGE KEY

To attain the goals of a National Forest (provide wildlife, wood, water, forage and recretation) the Forest's staff is involved in many kinds of activities, described in table 5-1.

Additional activities not directly related to a forest stand (road construction power or gasline construction, dam construction) may also be encountered. All these may result in many levels of various changes to which must be added all the natural changes such as diseases, blown down timber, avalanches, landslides and beaver pounds. These changes may not be all detected from an airborne or spaceborne sensor as seen with the DIADS approach. A particular hierarchical classification of the changes for use on a change detection task had to be attempted. A dichotomous key was selected because it seemed the best suited for use by the Forest Service. The various data used and approaches investigated during the study lead to two major observations:

- Some changes were detected using all the approaches but others were only detected by some of the approaches.
- A complete description of the changes as required in the land management planning process is based on human activities and not on the cover types; thus, this level of description can only be assessed in a final step or only by means of records.

TABLE 5-1. Partial Listing of Various Practices Resulting in Disturbed Land Cover Condition Amenable to Change Detection

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<u>Timber Cutting</u>

Precommercial Thin
Commercial Thin
Shelterwood Preparation
Shelterwood Seed Tree
Shelterwood Removal
Clearcut
Selection

<u>Site Preparation and Reforestation</u>

Hand or Tractor Blade Scalp
Contour Scalp
Roller Chop
Prescribed Burn
Root Plow
Brush Rake

<u>Range or Wildlife Betterment</u>

Chaining
Roller Chop
Root Plow
Brush Rake
Prescribed Burn
Drill (range seeding)
Pitting
Furrow
Chemical
Mechanical but Unknown Method

A three step change key is therefore proposed (see figure 5-2 and 5-3):

1. the first level should be a minimum requirement for a change detection and identification task in a forest
2. the second level requires probably an initialization of the classification with some training sets in the case of an automatic change detection and identification
3. the third level is the final description of the change that the forest personnel can use to define the class to which the changed area now belongs (in the forest classification system)

In this dichotomous key, the loss or gain of vegetation may be more related to a variation of reflectance (vegetative index or greenness in the case of CVA) than to a real change in the amount of vegetation.

For use as a change map, each delineated area should comprise the affected cover type and the areal extend of the change. This information may also be useful for updating the cover classification map of the Forest.

In the case of the first run of ERIM's CVA/BLOB algorithm on the San Juan National Forest, the Forest personnel felt that there was no need to go further than a "change - no change" classification. This level of classification might be enough for a District level use, but the change detection procedures being developed for currently updating the Forest data base, an automatic higher level of classification should be attempted.

Procedures for going from the identification of the change to the new cover class should be developed also in the context of the change detection task.

1st Step			2nd Step			DESCRIPTION
A	B	C	D	E	F	
0						NO CHANGE
1						CHANGE
	0					NON-VEGETATED AREA
	1					VEGETATED AREA
		0				LOSS OF VEGETATION
		1				GAIN OF VEGETATION
			0			NON-FORESTED AREA
			1			FORESTED AREA (Hardwood and softwood may need to be separated here for further classification)
				0		TOTAL (LOSS OF VEGETATION)
				1		PARTIAL
					0	HUMAN ACTIVITIES RELATED CHANGES
					1	NON-HUMAN ACTIVITIES RELATED CHANGES

TABLE 5-2. DICHOTOMOUS DESCRIPTION OF AREA CONDITION WITHIN TWO STEPS (LEVEL 2).

A	B	C	D	E	F	
0						NO CHANGE
1	0					URBAN TO URBAN, LANDSLIDE OR EROSION ON A BARE SOIL
1	0	1				BARE SOIL TO CROP OR URBAN DESTRUCTION AND VEGETATION REGROWTH
1	1	0	0	0	0	ROAD, HOUSE, POWER OR GAS LINE CONSTRUCTION, AGRICULTURAL CONVERSION, NEW IMPOUNDMENT, INCREASE IN WATER LEVEL, MINE DRILLING SITE
1	1	0	0	0	1	FLOODING, INCREASE IN WATER LEVEL, EROSION, LANDSLIDE
1	1	0	0	0	0	LAND CLEARING; AGRICULTURAL CONVERSION, RANGE OR WILDLIFE BETTERMENT
						SITE PREPARATION, REFORESTATION
						CHEMICAL, MECHANICAL OR BURNING (PRESCRIBED)
1	1	0	0	1	1	DROUGHT, DISEASE
1	1	0	1	0	0	HARVESTING (CLEAR CUTTING) (HARDWOOD OR SOFTWOOD)
1	1	0	1	0	1	WILDFIRES, BLOWN DOWN TIMBER, DISEASE (HARDWOOD OR SOFTWOOD)
1	1	0	1	1	0	SILVICULTURAL TREATMENT, SELECTIVE CUTTING, THINNING, PRESCRIBED BURNING
1	1	0	1	1	1	STRESS, WILDFIRE, DISEASE
1	1	1	0			REGENERATION
1	1	1	1			TREE GROWTH

TABLE 5-3. THIRD STEP, IDENTIFICATION OF CAUSE RELATED TO DISTURBANCE/CONDITION

5.2 CVA/BLOB APPROACH

5.2.1 DESCRIPTION OF THE CVA/BLOB ALGORITHM

In this section only an overall description of the algorithm will be presented; further information may be found in ERIM's publications.

The Landsat data are first geometrically corrected, restored and resampled at 50 meter intervals and registered to the map.

The CVA technique defines multitemporally spectrally homogeneous terrain patches through BLOB analysis of tasseled-cap brightness and greenness variables computed on two dates. The tasseled-cap transformation consists of linearly combining four Landsat channels in two values: brightness (indicator of overall reflectance) and greenness (indicator of vegetation). The brightness is aligned generally with the direction of variations in the reflectance of bare soil. The greenness is orthogonal to the brightness in the plane of principal variations and usually on the directions of signals from healthy vegetation. The BLOB algorithm introduces spatial coordinates of each pixel into the vector description of the pixel and uses this information along with the spectral channel values in a conventional unsupervised clustering of the scene. It thus isolates spectrally homogeneous patches called BLOBS. The spectral mean vector of BLOB is then regarded as a defined feature. BLOBS are examined sequentially and a decision as to whether the BLOB has changed or not between observation dates is made using the variation in greenness and brightness. A BLOB is defined as changed BLOB if the magnitude of the change vector exceeds a user specified threshold. The magnitude of the change vector is computed as:

$$cv = \sqrt{\frac{(C_2 - G_1)^2}{\sigma_G} + \frac{(B_2 - B_1)^2}{\sigma_B}}$$

where: G_2, G_1 are the greenness digital mean values of the BLOB on day 2 and day 1

B_2, B_1 are the corresponding brightness values

σ_G, σ_B are user specified coefficient

CV is the change vector

Change identification is made by looking at the direction of the change.

$$\theta = \arctan \frac{(G_2 - G_1)}{(B_2 - B_1)}$$

A two-channel lookup table procedure is used on the data (greenness, brightness) from either date for forest - nonforest stratification before the change identification.

5.2.2 EVALUATION OF THE CAPABILITIES

- The Tasseled-Cap transformation. While reducing the amount of data to be manipulated, the tasseled-cap transformation combines the four Landsat channels in a way to use most of their information. But the linear combination was created for agricultural purposes and may not be adapted to all kinds of remote sensing studies. Other orthogonal values may be useful for detecting changes in a forested area. The results of the ERIM's study in San Juan National Forest should help assessing this problem. Using some known reflectance characteristics on changed areas,

research of other combinations of bands in the tasseled-cap transformation may help to focus the change detection on specific types of changes.

- The BLOB algorithm. The BLOB algorithm has the capability of smoothing and compressing the data. The data compression is particularly important in automatic change detection over large areas. The reduction of the salt and pepper appearance seems a good asset for any work in the San Juan National Forest. The comparison of BLOB mean spectral vectors instead of pixel values negates some problems related to a pixel-by-pixel change detection. The main problem was commission errors due to the imperfect image-to-image registration. The introduction of spatial coordinates in the clustering algorithm will be of special interest because of its effect on the treatment of boundary pixels. This interest is increased in the San Juan National Forest where both partial and clear cutting occur. A lot of clear cut areas being of small size, the percentage of mixed pixels (forest/clear cut) is important and their reflectance values are similar to those of partial cuttings. Without the spatial attribute, those pixels could be misclassified at this level. Current research on the effect of the parameters on the BLOB creation is conducted at ERIM. The shape of the BLOB does not seem to be independent from the blobing procedure. The shape of the BLOB should be examined in relation to the parameters and the way of measuring the spatical distances during the creation of the BLOB.

- The CVA algorithm. The criteria for the creation of the forest - non forest look up table used in prior change detection study in Kershaw County, South Carolina, may be also used in this area, but an additional look up table will probably have to be created for separating brushes from timber because of spectral variations of land clearings in oak brushes and cuttings in aspens are similar, as shown on the previous results. This of course will have to be done only according to the level of classification required.

  The CVA thresholds will probably be more difficult to set them in the Kershaw County study because of the type of changes that occur in the Forest.

  The success of these threshold settings for identifying the changes will be one of the most important results to be assessed for evaluting the use of CVA/BLOB in a production mode.

  Although this algorithm has already given good promising results in previous studies, the big amount of processing leading to the change vectors make the output of the BLOB/CVA difficult to interpret and, without routinization of the procedures (parameter setting) this algorithm cannot be used in an operational mode.

  The evaluation of the results in the San Juan National Forest will permit to really assess the capabilities of this algorithm. If the results are satisfying in the San Juan National Forest, everyone involved in the study feels that this algorithm could then be used in a production mode almost anywhere.

6. CONCLUSIONS

Even if all the changes related to human activity are recorded at the District level, there is a need to detect changes systematically at the Forest level for updating the data base or monitoring progress in relation to the forest land management plan. This is due to the fact that in each District, the changes are roughly delineated on maps with different individual labels used by each functional specialist (Range, Wildlife, Timber) to suit their needs rather than applying a standard legend. In addition, there is an important need to locate and identify natural changes.

The study shows that the association of landforms and vegetation cover types on San Juan National Forest presents a difficult and technically challenging setting for automatically detecting change for updating the data base. Thus, the Forest appears to be a good test site for implementing and assessing the capabilities of the CVA/BLOB algorithm and improving it for a later use in a production mode if needed. The problems encountered in this study as well as in the automatic classification of vegetation cover types using Landsat data show that the characteristics of the area are also ideal for testing the contribution of a terrain model in mapping the vegetation cover types and thereby improving the results of an automatic change detection and identification.

The interpretation of the LFC high altitude photography provided a good ground truth and shows that it may even be used for detecting changes in a relatively large area. DIADS, although all the problems encountered, proved to be a useful tool for conducting this feasibility study.

The San Juan National Forest required only a change - no change classification using CVA/BLOB. This study should be used as a test and evaluation of the algorithm and thus should go farther than this level of classification. This would allow the characteristics of the area to improve the technique and understand the problems of a change detection task in such an area (i.e. detecting regrowth in cover types with high reflectance variability).

If the Forest staff wants to use a RAS terminal to run the CVA/BLOB algorithm, the parameter setting needs to be routinized. This routinization can only be assessed if the classification goes beyone the change - no change level.

If this change detection task were to test the CVA/BLOB algorithm there area needs to go beyond the San Juan National Forest requirements. Besides, the higher level of identification of the change, the updating of the data base.

REFERENCES

Mazade, A.V., C. A. Underwood, J. F. Ward, and S. S. Yao. 1979. Remote Sensing and Comptuer-Based Vegetation Mapping in the San Juan National Forest. Final Report. LEC-13215. (Houston, TX). NFAP-173.

Colwell, J., G. Davis, and F. Thomson. 1980. Detection and Measurement of Change in Production and Quantity of Renewable Resources. Final Report. ERIM 145300-4-F. (Ann Arbor, MI). NFAP-202.

Aldrich, R. C. 1975. Detecting Disturbances in a Forest Environment. Photogramm. Eng. 41.

Earth Resources Laboratory, NASA. 1980. The Use of Landsat MSS Data for Detecting Land Cover Changes.

F.H. Eyre (Editor). 1980. Forest Cover Types of the United States and Canada. Society of American Foresters.